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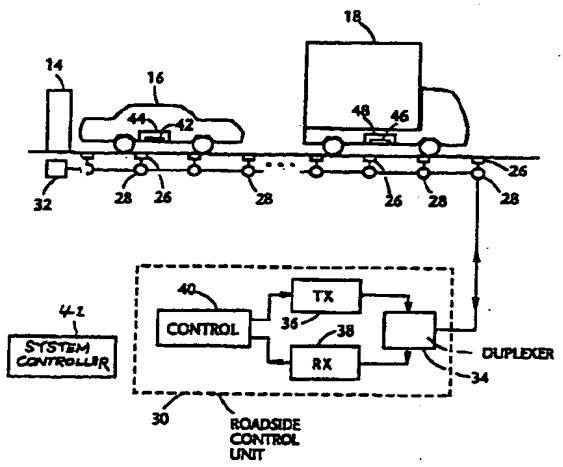
## (54) Electronic toll collection system and method featuring antenna arrangement

(57) In order to establish radio communications between an in-vehicle unit mounted on a vehicle and a roadside unit, an on-board antenna is mounted on the vehicle. The on-board antenna is operatively coupled to the in-vehicle unit and has directivity toward a road surface. Further, a stationary antenna means is operatively coupled to the roadside unit. The stationary antenna is provided at approximately center portion of a vehicle lane in a manner to have directivity toward an upward direction. Thus, a very short distance of radio communication can be formed thereby to eliminate a radio wave interference caused by a big vehicle.

**FIG. 2**

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## Description

**[0001]** The present invention relates generally to improved techniques for establishing radio communications between a vehicle and a roadside network, and more specifically to such techniques for use in ITS (intelligent transportation systems). Still more specifically, the present invention is well suited for effectively establishing radio communication links between an in-vehicle unit and a roadside unit in a ETC (electronic toll collection) system.

**[0002]** In an effort to solve a variety of transportation problems, a broad range of diverse technologies, known collectively as ITS, have been proposed. Among others, the ETC system has been found extremely preferable to eliminate traffic congestion and backups on toll booths.

**[0003]** Before turning to the present invention, it is deemed advantageous to briefly describe, with reference to Fig. 1 , a conventional technique that may be relevant to the present invention.

**[0004]** As shown in Fig. 1, an antenna 10 is provided high on a pole 12 that is located on a roadside. When a moving vehicle approaches a toll facility or booth (not shown), the vehicle is detected using an approaching vehicle detecting unit 14 that is usually comprised of two devices located on each side of a lane (as best shown in Fig. 3). In Fig. 1, two vehicles 16 and 18 are schematically illustrated, which carry respectively in-vehicle units 20 and 22 for establishing a two-way communication with a roadside network through the antenna 10. Each of the units 20 and 22 is located on a dashboard and includes an antenna (not shown). However, the above-mentioned conventional technique suffers from the following problem. That is, if the vehicle 16, which is a usual sedan in this case, approaches the pole 12 (viz, toll booth) immediately following the vehicle 18 (viz., a truck with a tall cargo room), the radio communication between the in-vehicle unit 20 and the antenna 10 is undesirably blocked. Since the radio communication is made via a direct wave, the quality of data to be transmitted is deteriorated to such an extent that the data is not correctly exchanged.

**[0005]** Accordingly, what is desired is to establish radio communication links which are not blocked by a tall vehicle.

**[0006]** It is therefore an object of the present to provide a technique via which a radio communication path is not blocked by a preceding tall vehicle.

**[0007]** Another object of the present invention is to provide a technique via which a radio communication can be established using an extremely small electromagnetic power.

**[0008]** In brief, these objects are achieved by techniques wherein in order to establish radio communications between an in-vehicle unit mounted on a vehicle and a roadside unit, an on-board antenna is mounted on the vehicle. The on-board antenna is operatively coupled to the in-vehicle unit and has directivity toward a road surface. Further, a stationary antenna means is operatively coupled to the roadside unit. The stationary antenna is provided at approximately center portion of a vehicle lane in a manner to have directivity toward an upward direction. Thus, a very short distance of radio communication can be formed thereby to eliminate radio wave interference caused by a big vehicle.

**[0009]** One aspect of the present invention resides in a system for establishing radio communications between an in-vehicle unit mounted on a vehicle and a roadside unit, comprising: an on-board antenna mounted on the vehicle, the on-board antenna being operatively coupled to the in-vehicle unit and having directivity toward a road surface; and stationary antenna means operatively coupled to the roadside unit, the stationary antenna being provided at approximately center portion of a vehicle lane in a manner to have directivity toward an upward direction.

**[0010]** The features and advantages of the present invention will become more clearly appreciated from the following description taken in conjunction with the accompanying drawings in which like elements are denoted by like reference numerals and in which:

Fig. 1 is a diagram schematically showing part of an ETC system wherein an antenna coupled to a roadside network communicates with an in-vehicle unit mounted on a moving vehicle, having been referred to in the opening paragraphs;

Fig. 2 is a diagram schematically showing a first embodiment of the present invention;

Fig. 3 is a diagram schematically showing two vehicles on a lane for a better understanding of the first embodiment shown in Fig. 3;

Fig. 4 is a gram schematically showing a second embodiment of the present invention; and

Fig. 5 is a sketch showing a leaky coaxial cable which is applied to the second embodiment of the present invention.

**[0011]** A first embodiment of the present invention will be described with reference to Figs. 2 and 3. The portions already referred to with respect to Fig. 1 will not be described for brevity.

**[0012]** As shown, a plurality of antennas 26 is provided in a manner to be embedded at a center portion of a lane 24 (Fig. 3). More specifically, the antennas 26 are coupled in series and provided along a centerline of the lane 24. Each antenna 26 may be a plate-like antenna such as a microstrip antenna. However, the antennas, used in the present invention, are in no way limited to the plate-like antenna and may take the other form if it is suitable to be located on the lane or embedded therein. By way of example, a microstrip antenna, which may preferably be used with the present invention, is disclosed in a paper entitled "Broadbanding of a Microstrip Antenna" by H. Ozeki, et al., published March 1997 by "The Institute of Electronics, Information and communi-

cation engineers" of Japan. As an alternative, a microstrip antenna, which can be used as the antenna 26, is disclosed in a paper entitled "A consideration on Shorted Microstrip Antenna" by H. Yamamoto, et al., published March 1997 by the same Institute as mentioned above. It is understood that each of the antennas 26 has directivity in an upward direction.

**[0013]** The antennas 26 are respectively coupled to corresponding devices 28 for splitting and combining signals. That is, the signal outputted from a roadside control unit 30 is split or divided at each device 28 and then applied to the corresponding antenna 26 (downlink). On the other hand, the signals from the antennas 26 are combined at the signal splitting/combining device 28 (uplink). One end of the serially connected devices 28 is coupled to a terminator 32, and the other end thereof is coupled to the roadside control unit 30 which comprises a duplexer 34, a transmitter 36, a receiver 38, and a controller 40.

**[0014]** Another controller 41 is provided to supervise an overall operation of the electronic toll collection system to which the present invention is applicable. However, the controller 41 is not directly concerned with the present invention and thus a detailed description thereof will be omitted for the sake of simplifying the disclosure. For further details of the operation of the ETC system, reference should be made to U.S. Patent No. 5,424,727 granted to Jin S. Shieh.

**[0015]** As shown in Fig. 2, the vehicle 16 carries an antenna 42 which is installed within an in-vehicle (or on-board) unit 44 in the illustrated case. However, it is practically preferable to separately provide the antenna 42 with respect to the in-vehicle unit 44, in the case of which the antenna 42 is operatively coupled to the unit 44 via a suitable cable. In Fig. 2, the antenna 42 faces the road surface through an opening (not shown) whereby the antenna 42 has directivity toward the lane (road) surface. Thus, a two-way radio communication link can be established between the antenna 42 and the corresponding antenna 26. In exactly the same manner, the other vehicle 18 is also equipped with an antenna 46 that is coupled to an in-vehicle unit 48. Fig. 3 is a schematic plan view showing a manner where each of the vehicles 16 and 18 travels while the corresponding in-vehicle unit communicate with the roadside control unit 30 via the antennas 42 (or 46) and 26. In Fig. 3, each reference numeral 50 depicts a vehicle wheel.

**[0016]** The first important feature of the present invention is that there exists no problem that the radio link may be interfered by an obstacle (such as a big vehicle as in the prior art). The second important feature of the present invention is that the radio link can well be established using an extremely small electromagnetic power. This is highly preferable in that the instant invention can be used without consideration of the very strict radiation power regulations in most countries.

**[0017]** In the above, the antenna 42 may be installed in other suitable portions of the vehicle 16, such as a rear or front portion of the vehicle 16, under the condition that the electric wave can be directed toward the road surface.

**[0018]** The operation of the first embodiment will briefly be described. The frequencies used for the uplink and downlink are usually different. The data is transmitted using multiple access techniques such as slotted-ALOHA. The data communication is carried out on a frame basis wherein each frame is comprised of two to 5 slots. One phase is transmitted using one slot. When a vehicle is detected at the detecting unit 14, the control unit 40 activates the transmitter 36 and assigns a slot to the detected vehicle. Therefore, it is possible for the control unit 40 communicates a plurality of vehicles through the use of plural slots.

**[0019]** A second embodiment of the present invention will be described with reference to Figs. 4 and 5.

**[0020]** The second embodiment differs from the first embodiment in that the second embodiment uses a leaky conductive line 52 in place of the combined arrangement of the antennas 26 and the devices 28 (Fig. 2). The leaky conductive line 52 has one end coupled to a terminator 69 and the other end coupled to the roadside control unit 30. Other than this, the second embodiment is substantially identical with the first one and accordingly, the descriptions of the portions already referred to in relation to Figs. 2 and 3 will be omitted for simplifying the disclosure.

**[0021]** One example of the leaky conductive line 52 is a leaky coaxial cable that is disclosed in a paper entitled "Characteristics of a leaky coaxial cable with slots along a zigzag line" by T. Nakahara, et al., published in 1967 by "The Institute of Electronics, Information and communication engineers" of Japan. As shown in Fig. 5, the above mentioned leaky coaxial cable (denoted by 52') comprises an inner conductive pipe (made of aluminum (for example)) 54 which is provided interior of an outer conductive tube 56. A plurality of rectangular slots 58 is provided along a zigzag line. A distance between center portions of adjacent slots is approximately equal to one wavelength of a radio wave to be used. In accordance with the aforesaid paper, the leaky coaxial cable 52' with the slots provided in zigzag is able to strengthen a leaky wave mode while suppressing a surface wave mode of fundamental wave. Accordingly, it is possible to effectively uniform the electromagnetic field distribution in the vicinity of the cable. It is to be noted that although the term "leaky" is used, the cable 52' is able to receive the electric wave in addition to the transmission of the electric wave. In the above, a space between the inner conductive pipe 54 and the outer tube 56 is filled by a suitable dielectric material. Further, although not shown in Fig. 5, a protective resin film is used to cover the outer tube 56.

**[0022]** Noting that the use of the leaky coaxial cable 52' is exemplary and the instant invention is in no way limited thereto. That is, a leaky waveguide is also applicable to the instant invention. It is understood that the

second embodiment is advantageously simple in construction compared with the first embodiment which includes the combined arrangement of the antennas 26 and the signal splitting/combining devices 28.

**[0023]** In the foregoing, the present invention has been discussed when applied to the ETC system. However, it is to be noted that the instant invention is applicable to establish radio communications between moving vehicles and the roadside network.

**[0024]** It will be understood that the above disclosure is representative of only two possible embodiments of the present invention and that the concept on which the invention is based is not specifically limited thereto.

## Claims

1. A system for establishing radio communications between an in-vehicle unit mounted on a vehicle and a roadside unit, comprising:

   an on-board antenna mounted on said vehicle, said on-board antenna being operatively coupled to said in-vehicle unit and having directivity toward a road surface; and
   stationary antenna means operatively coupled to said roadside unit, said stationary antenna being provided at approximately center portion of a vehicle lane in a manner to have directivity toward an upward direction.

2. A system as claimed in claim 1, wherein said radio communications are used for use in electronic toll collection system.

3. A system as claimed in claim 1, or 2 wherein said on-board antenna is provided a bottom portion of said vehicle, a front portion of said vehicle, or a rear portion of said vehicle.

4. A system as claimed in claim 1, 2, or 3 wherein said stationary antenna comprises a plurality of antennas provided in a vehicle travelling direction within said vehicle lane.

5. A system as claimed in claim 4, wherein said plurality of antennas is respectively coupled to a plurality of signal devices which are connected in series and each of which branches and synthesize a signal.

6. A system as claimed in claim 1, 2, 3, 4 or 5 wherein said road side antenna means is a leakage conductive line which transmits and receives electric waves, said leakage conductive line being provided in a vehicle lane and in a vehicle travelling direction.

# FIG. 1
# (PRIOR ART)

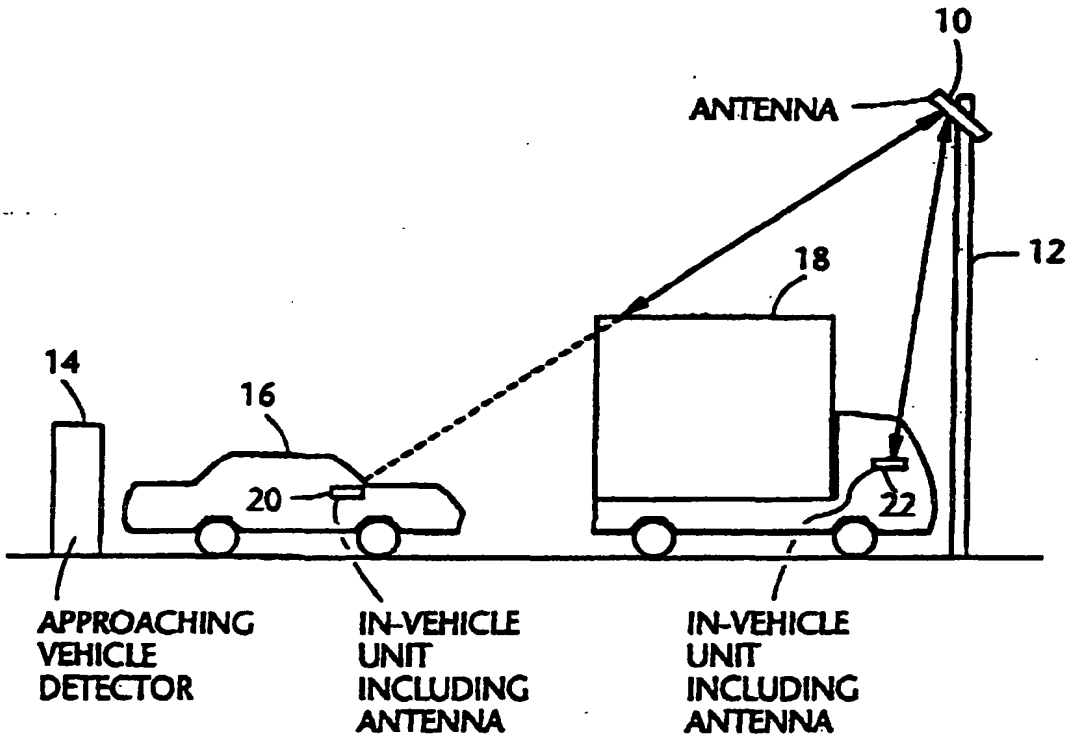

FIG. 2

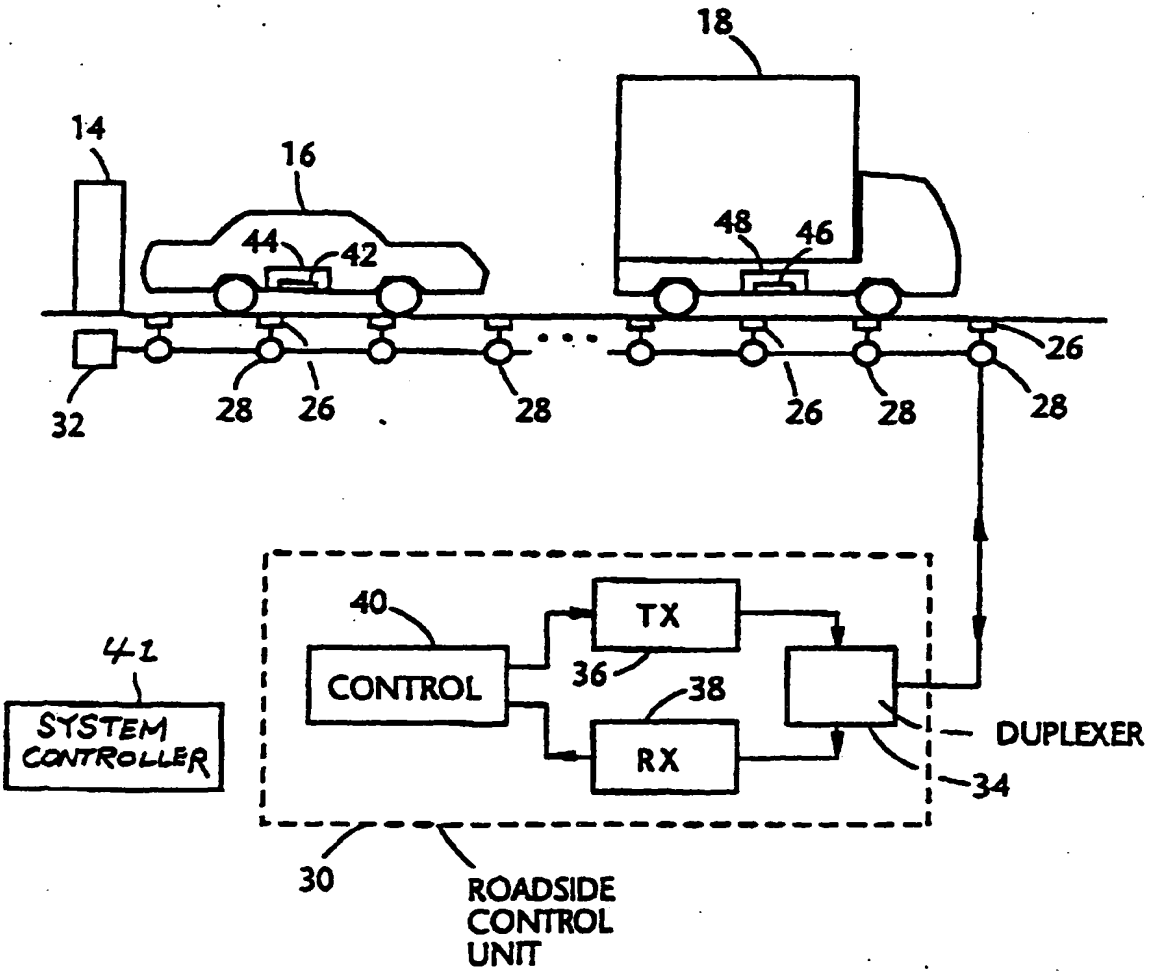

FIG. 3

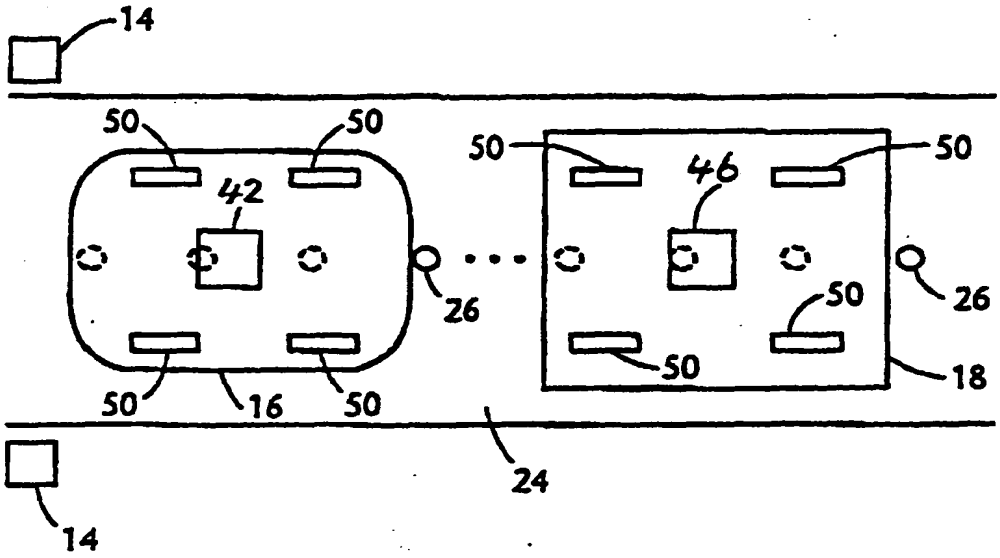

FIG. 4

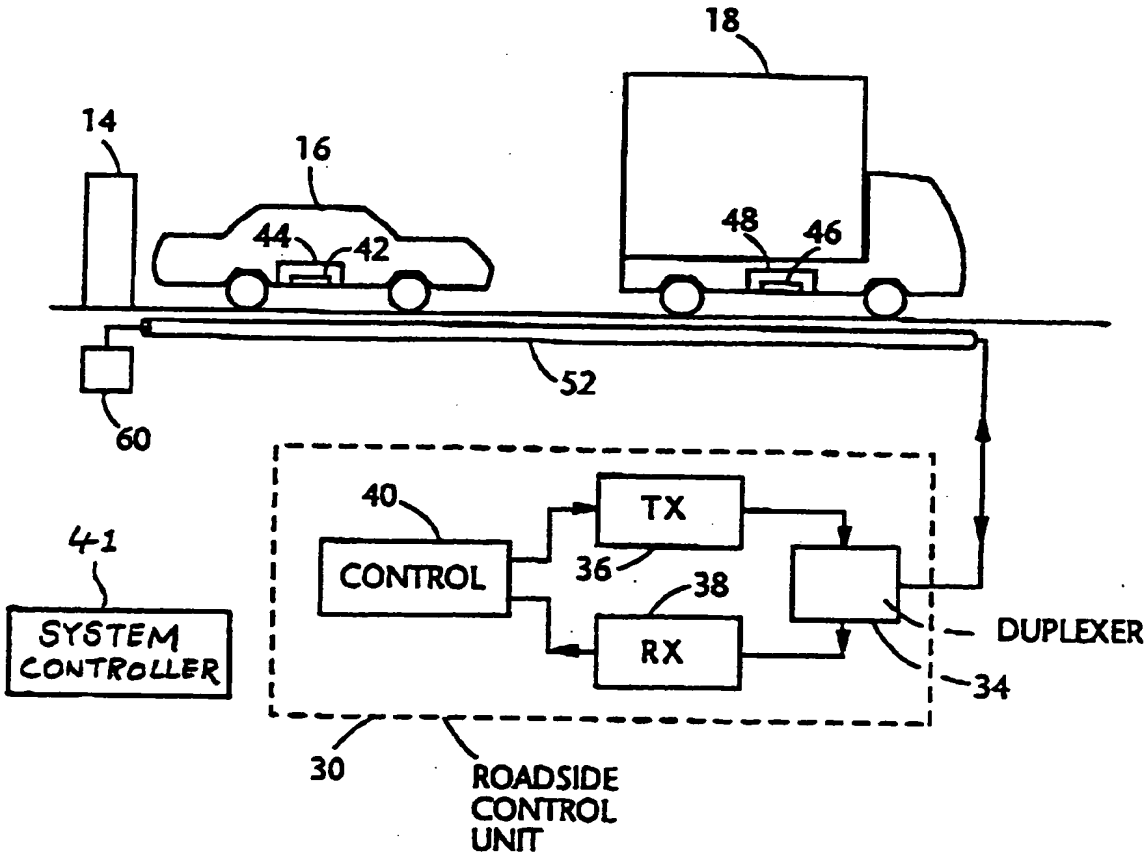


FIG. 5

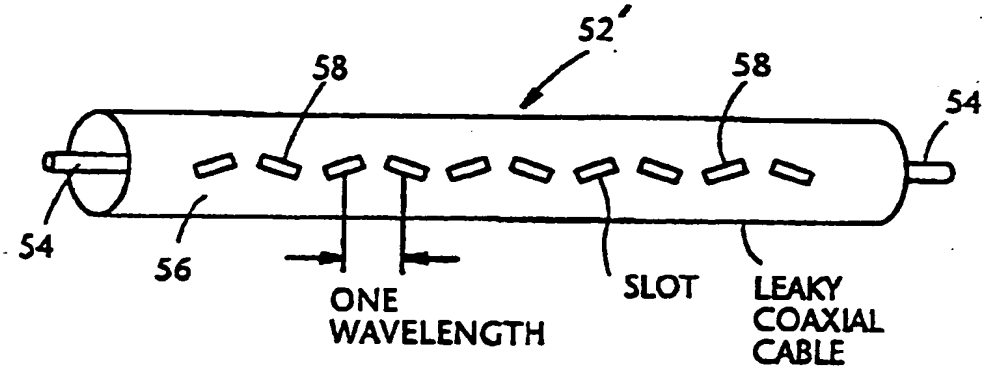

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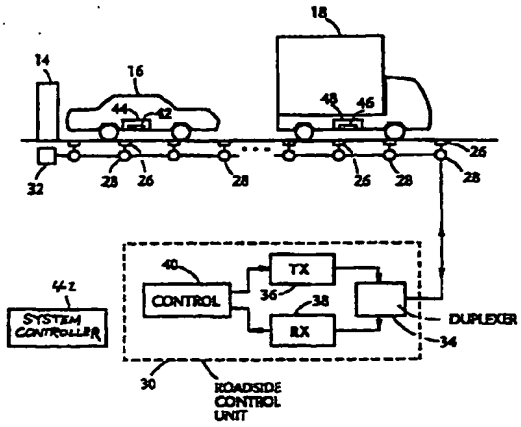
FIG. 2

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# EUROPEAN SEARCH REPORT

Application Number
EP 98 12 1288

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G08G
G07C

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| THE HAGUE | 18 February 2000 | Meyl, D |

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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